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THE INTEGRATED BRIDGE SYSTEM (IBS) PROJECT.(U)

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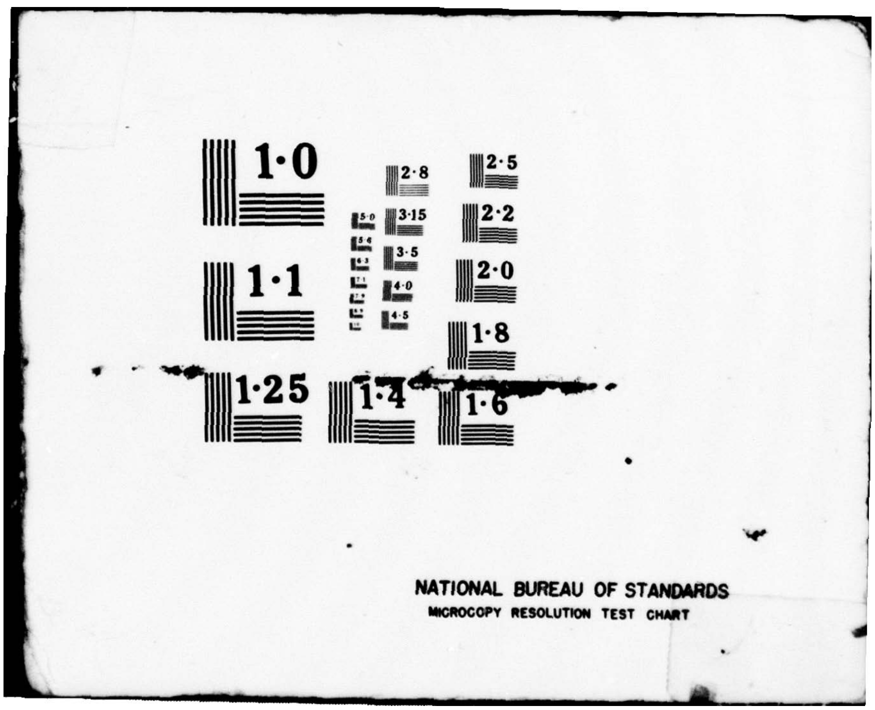
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THE INTEGRATED BRIDGE SYSTEM (IBS) PROJECT: FINAL REPORT

LEVEL II

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

THE INTEGRATED BRIDGE SYSTEM (IBS) PROJECT: FINAL REPORT

by

Robert A. Sniffin
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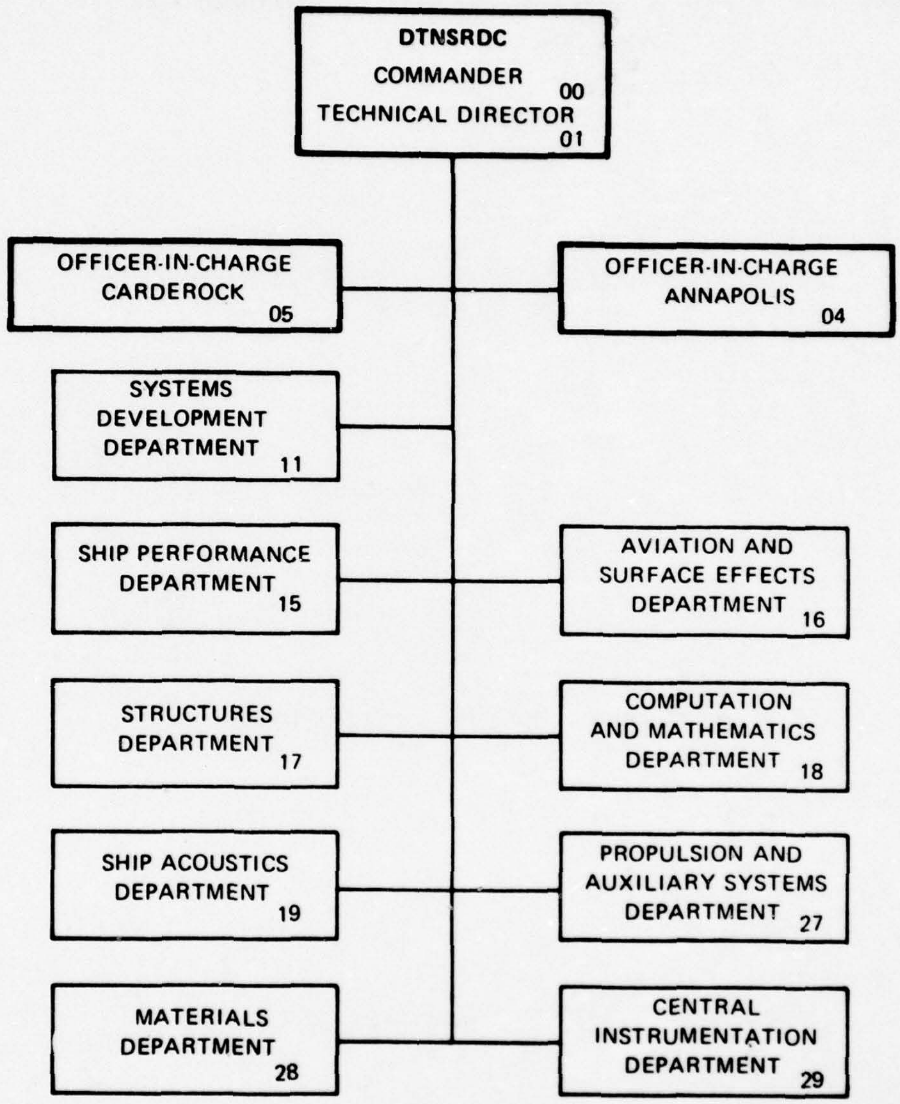

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1084) and tested at sea over a seven month period. After more than 1800 hours of underway test and evaluation it was demonstrated that bridge watch manning could be reduced substantially while improving bridge effectiveness. During most routine independent and formation steaming operations there were four watchstanders in the pilot house: an Officer of the Deck, a Junior Officer of the Deck, a Steering and Propulsion Operator, and a Quartermaster of the Watch. A forward and aft lookout were stationed at all times. Ratings of bridge effectiveness showed the integrated bridge system to be significantly more effective than a conventional bridge in all functional areas except visual surveillance.

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LIST OF ABBREVIATIONS

A	Availability (Operational)
AFT LO	After Lookout
ASROC	Anti Submarine Rocket
ASW	Anti Submarine Warfare
BMOW	Boatswain's Mate of the Watch
BR/BR TLKR	Bridge-to-Bridge Talker
BRG RCDR	Bearing Recorder
BRG TKR	Bearing Taker
CIC	Combat Information Center
CNO	Chief of Naval Operations
CO	Commanding Officer
COMP	Comparative Scale
CPA	Closest Point of Approach
DCU	Data Converter Unit
DR	Dead Reckoning
DTNSRDC	David W. Taylor Naval Ship Research and Development Center
EFF	Effectiveness Scale
EMCON	Emission Control
EOT	Engine Order Telegraph
F	Farenheit
FATH OPER	Fathometer Operator
FORM STMG	Formation Steaming
FWD LO	Forward Lookout
HELO OPS	Helicopter Operations

LIST OF ABBREVIATIONS

IBS	Integrated Bridge System
INDEP STMG	Independent Steaming
ISE	Independent Steaming
JOOD	Junior Officer of the Deck
LOW VIS	Low Visibility
MMH	Maintenance Man Hours
M&N	Maneuvering and Navigation
MOB	Man Overboard
MSGR	Messenger
MSI	Maintenance Support Index
MTBF	Mean Time Between Failures
MTFL	Mean Time to Fault Locate
MTTR	Mean Time to Repair
NS	Non Significant
OOD	Officer of the Deck
PAD	Predicted Area of Danger
PILOT	Piloting
PPC	Point of Possible Collision
QMOW	Quartermaster of the Watch
READ COND	Readiness Condition
S&P	Steering and Propulsion
SS	Sea State
SSTG	Ship's Service Turbine Generator
TICC	Tactical Information and Communication Console
UNREP	Underway Replenishment
VDS	Variable Depth Sonar

ABSTRACT

Rising manpower costs along with diminishing manpower resources require more efficient utilization of available shipboard personnel to maintain operational readiness of the Fleet. To meet this need, an integrated bridge system was developed to demonstrate the feasibility of reducing bridge watch manning requirements while maintaining or improving effectiveness. The system was designed to provide two centralized work stations from which bridge watchstanders could perform all bridge functions during routine steaming operations. The system was installed onboard USS MCCANDLESS (FF 1084) and tested at sea over a seven month period. After more than 1800 hours of underway test and evaluation it was demonstrated that bridge watch manning could be reduced substantially while improving bridge effectiveness. During most routine independent and formation steaming operations there were four watchstanders in the pilot house: an Officer of the Deck, a Junior Officer of the Deck, a Steering and Propulsion Operator, and a Quartermaster of the Watch. A forward and aft lookout were stationed at all times. Ratings of bridge effectiveness showed the integrated bridge system to be significantly more effective than a conventional bridge in all functional areas except visual surveillance. This report describes the integrated bridge system and the results of the at-sea demonstration.

ADMINISTRATIVE INFORMATION

The development and test of the Integrated Bridge System (IBS) was conducted by the Shipboard Manning and Automation Project Office, David W. Taylor Naval Ship Research and Development Center (DTNSRDC, Code 2784) under the supervision of Cdr. J. Dachos, Cdr. P. McCammon and Mr. J. Corder. The program administrator was Mr. A. Rubinstein, Naval Material Command (MAT 08T244) and the program monitor was Mr. J. Sejd, Naval Sea Systems Command (SEA 0322). Robert A. Sniffin, the principle author, from the Navy Personnel Research and Development Center was stationed at the DTNSRDC project office during the test and evaluation phase of the program. Fleet operational support during the test and evaluation was provided by Lcdr. A. VanAllman, Operational Test and Evaluation Force (Code 732) under Project 226-DT/OT II assigned by the Chief of Naval Operations (OP98). The work was funded initially under Program Element Number 62763N in Task Area SF5552521Z and completed under Program Element Number 62757N in Task Area SF55525291. The work was accomplished under DTNSRDC Work Unit 2784-105. Special appreciation is extended to the Commanding Officer, ship's officers and crew of USS MCCANDLESS (FF 1084) for their outstanding cooperation and assistance during installation, test, and evaluation of the IBS aboard their ship from October 1976 through August 1977.

INTRODUCTION

BACKGROUND

In response to the need for a coordinated effort to reduce costly shipboard manning resources, the Chief of Naval Operationa (CNO) by CNO/VCNO Action Sheet 303-72 of 19 May 1972, directed the Chief of Naval Material to establish a coordinated R&D program which had reduction in personnel manning as its overall goal. On 13 June 1972, CNO followed up by issuing Action Sheet 333-72, which directed that a bridge manning reduction pilot program be initiated immediately to find ways to reduce bridge watches on existing ships. The Shipboard Manning and Automation Project Office was established in July 1972 at DTNSRDC for this purpose. Based on the results of 17 ships participating in the pilot program, it was determined that a significant reduction in bridge watchstanding could be achieved through integration of existing equipment and introduction of automation into a centralized work station for bridge watchstanders. Consequently, an integrated bridge system (IBS) was designed, developed and tested aboard a U.S. Navy ship.

PURPOSE

The purpose of the Integrated Bridge System Project was to demonstrate the feasibility of achieving a reduction in bridge watch manning while maintaining or improving ship readiness and operational effectiveness.

APPROACH

A general human factors orientation was followed in the design process. In 1973 a survey was conducted to determine the information requirements of the bridge. Approximately two hundred destroyer line officers were interviewed to identify bridge task requirements. This information was translated into equipment, control, and display requirements. Alternative designs were developed from these requirements and the principles of human engineering were applied to the designs. The results were then incorporated into a full-scale mock-up of a bridge work station. Anthropometric studies on the mock-up were conducted to determine effective control/display design configurations. Time and motion studies were conducted on the mock-up using typical destroyer scenarios and navy personnel with previous bridge experience. From these investigations a functional specification for an integrated bridge system was developed.[1,2*] A contract was awarded in 1974 for design, fabrication, installation, check-out, and support during at-sea trials of an integrated bridge system.

Installation of the Integrated Bridge System (IBS) onboard USS MCCANDLESS (FF 1084) commenced in November 1976. Final shipboard acceptance tests were completed in January 1977 followed immediately by full-scale at-sea trials. A comprehensive and detailed test plan was developed in August 1976 to guide the collection of data during the at-sea test of IBS.[3]

SYSTEM DESCRIPTION

GENERAL

The IBS is defined as that combination of men, equipment and procedures designed to perform all required functions of a ship's bridge. The functions include navigation, maneuvering, communications, surveillance, administration and safety. The goal of manning reduction with the same or improved effectiveness was to be achieved through centralization, consolidation, and automation of new and existing bridge equipment along with a redistribution of watchstander tasks and associated bridge procedures.

The system consisted of two major consoles and peripheral bridge and remote equipment. Figure 1 shows the general arrangement of the equipment that was located in the pilot house. The bridge equipment was laid out to maximize effective bridge operation within the constraints of the existing structure of the FF 1084. The equipment replaced by the IBS was removed for the duration of the demonstration.

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* A complete listing of references is given on page 37.

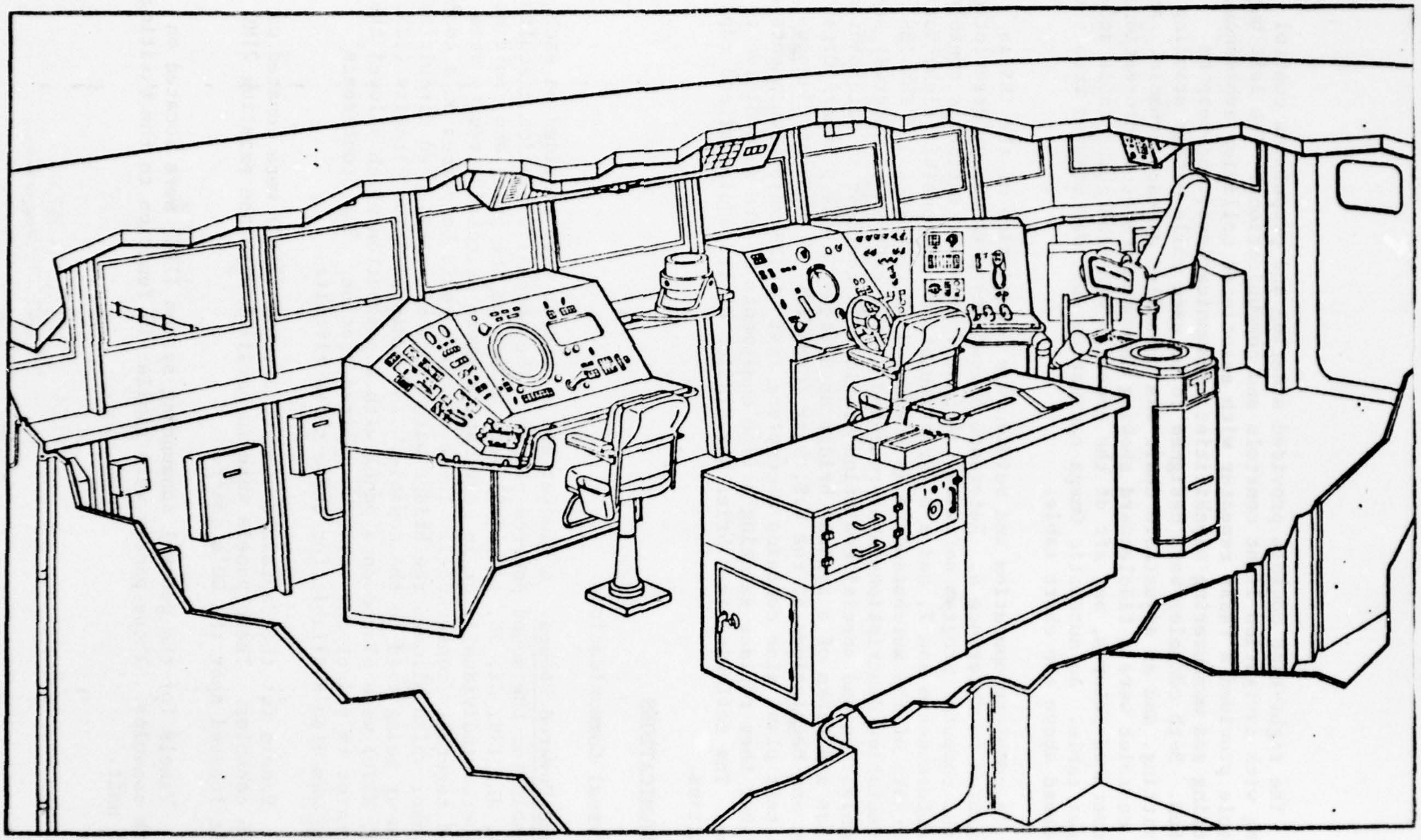

Figure 1 - Integrated Bridge System

The right-hand console provided steering and propulsion control along with navigation light controls and communications. The left-hand console provided a radar repeater with associated collision avoidance, piloting and maneuvering capabilities, communications, and weapons status. Both consoles were designed to be used while either standing or sitting, and an adjustable chair was installed at each console. Above the consoles were a fiddleboard showing engineering status information and an overhead pelorus, and aft of the consoles were the chart table and data logger table. An automatic Omega navigation unit was mounted from the overhead above the chart table.

A complete operation and maintenance description of the IBS is presented in reference 4. Reference 5 contains performance description of the computer program software. A functional description is contained in references 6 and 7, and a description of the responsibilities, duties, and tasks of IBS watchstanders is presented in reference 3. The IBS watchstation descriptions are presented in the context of underway watch organization and special evolution stations in contrast to watchstation duties and tasks of a typical bridge as defined in the Standard Organization and Regulations of the U.S. Navy (OPNAVINST 3120.32 of 23 August 1974). The test plan[3] also contains a complete list of IBS major equipments and whether they replace existing bridge equipments or are an addition to them. The following is a brief description of IBS equipment and capabilities.

COMMUNICATIONS

Internal Communications

Sound Powered Phones. A handset and a headset were provided on each console for the sound powered phones. The special evolution circuits (JA, JL, 1JV, JX, JC, 1JG, 1JS) were placed on one panel and could be selected individually or in combination where selected circuits were tied together (conference). These circuits could be placed on a loudspeaker which allowed the bridge watch to monitor selected circuit(s) without being tied to the console. The administrative circuits (1JX, X1J, X1JV) were placed on a panel with a pushbutton which allowed the operator to select and call the desired station. The "conference" mode was also available for these three circuits.

Panels for the Captain's command circuit (21MC) were located on both consoles. These panels were in parallel with the existing 21MC unit located near the CO's chair.

Panels for the general announcing system (1MC) were located on both consoles. These panels were similar in function to the exsiting 1MC unit.

A two way amplified voice communications range was located on the right console to allow the steering and propulsion operator to communicate with both bridge wings and the flying bridge.

Ship's Alarms. Guarded switches for the general, chemical, collision and flight crash alarms were located on the left console.

Manned and Ready System. A system was designed to allow various remote stations to report their manned and ready status for special evolutions nonverbally. The system consisted of a control panel on the left console, a status panel on the fiddleboard and remote box at appropriate locations throughout the ship. The control panel provided pushbuttons for the six special evolutions (General Quarters, Helo Detail, Special Sea Detail, Anchor Detail, Refueling Detail and Replenishment Detail) and the status panel displayed the manned and ready status of each of the stations for the selected evolution.

External Voice Communications. Each console had a radio handset and a selector switch which allowed the operator to select one of three bridge radio circuits, or the underwater telephone. On the left hand console volume controls were located for the loudspeakers associated with each of the circuits. A separate handset and volume control for the secure voice circuit was also located on this console.

SHIP CONTROL

Steering Control

An electronic steering system was installed to replace the existing synchro system. The system had three modes: (1) autopilot, (2) hand electric, and (3) nonfollow-up. In the autopilot mode, the desired heading was entered by a hand crank and was displayed on a digital display. Autopilot adjustments for various rudder responses, weather condition, rudder limits and alarm conditions were provided on a covered panel on the console. A remote autopilot input device was installed in the Combat Information Center. The hand electric mode provided normal steering similar in function to the existing system. The non-follow-up mode provided an emergency backup which bypassed all the bridge electronics and allowed the operator to use a lever engaging the hydraulic actuator installed in after steering to directly control steering. A display located on the console showed both helm order and rudder angle.

A standard gyro compass repeater was provided for normal steering and a remote indicating magnetic compass digital readout was provided as a backup for the gyro. The magnetic compass sensing unit was installed in the flying bridge in an area of minimum magnetic disturbance.

Motor controls for starting, stopping and monitoring the steering gear motor were also provided on the right console and were similar to existing controls.

Propulsion Control. Propulsion control for the IBS was in the form of a modified engine order telegraph (EOT) since FF-1052 Class ships do not have a direct throttle capability. The device was a single lever which was calibrated in engine orders, RPM, and speed and connected to both the ships EOT system and a new digital RPM order system. Fine RPM adjustment was accomplished by a thumbwheel located next to the lever. On the status panel were digital displays of ordered and answered RPM, actual RPM, and speed available.

MANEUVERING AND NAVIGATION

The maneuvering and navigation (M&N) system located in the left console had the following capability: radar display, collision avoidance, digital charting, and maneuvering board solutions. All automated solutions and digital functions were performed by an AN/UYK-20 computer located in the M&N console.

Radar Display

The main display was a sixteen inch high brightness radar display usable under any lighting condition without a hood. The display was in 945 line TV format with radar information provided through a digital scan converter. Range rings and a bearing cursor were provided as part of the scan converter with range and bearing of hooked symbols displayed as dedicated digital readouts. The display orientation could be either north up or course up. In the course up mode own ship could be moved from the center of the display half way to the lower edge of the display. Range scales of 2, 4, 8, 16, and 32 miles could be selected.

Collision Avoidance

Collision avoidance information was automatically calculated by the AN/UYK-20 computer based on the target course and speed and own ship's speed (similar to a torpedo intercept problem). The calculated points of possible collision (PPC) were displayed on the radar display at the end of a vector extending from the target which was the target's true course. If own ship's heading vector intersected the PPC then a potential collision situation existed. Similarly, danger area called a PAD (predicted area of danger) was calculated by the computer and displayed as an elipse around the PPC. The size of the PAD was based on an operator selectable minimum distance, or closest point of approach (CPA). If own ship's heading vector did not intercept the target's PAD, it indicated that the CPA for that target was greater than the preset value. If own ship or target changed course or speed a new calculation was made. Visible and audible collision avoidance alarms were automatically actuated for potential collision situations.

Target data was also displayed alphanumerically and included a target number, bearing, range, course, speed, CPA bearing, range and time. The four most threatening targets were displayed at all times. Other tracked targets could be called up by the operator as required.

The system provided for manual and automatic detection and acquisition, as well as automatic and manual tracking. Forty targets could be tracked automatically with five additional targets tracked manually. Targets not being tracked that passed through either of two preset guard rings could be detected and acquired automatically. Each guard ring was one mile wide and the radial distance from own ship was operator selectable. Audible and visual alarms were provided for both collision threats and newly detected targets.

Digital Charting

Digital chart information was presented on the radar display either in conjunction with the collision avoidance information or separately. The digital chart consisted of channel lines, straight line approximation of shore lines, shoal lines and significant features such as piers and bridges, selected visual aids, and selected radar aids. Each visual and radar aid was identified by number and letter and additional data on each aid such as color, name, light characteristics, etc. could be called up on the auxiliary display.

Initial positioning of the chart on the main display was based on the ship's latitude and longitude stored in the computer. The latitude and longitude was normally dead reckoned but could be automatically updated from the OMEGA system or manually via the data entry keyboard. Precise positioning of the chart was accomplished using the trackball to slew the chart to match the radar return. Automatic chart and radar alignment was maintained by automatically tracking designated fixed targets on the digital chart.

A visual piloting capability was also provided. The bridge wing peloruses were modified to allow a visual bearing to be displayed directly on the main display. The bearing taker dialed in the visual aid number (taken from the digital chart), sighted on the aid and pushed an "enter" button. The system then drew the line of bearing from the aid. When two or more lines of bearing were displayed the console operator positioned the hook symbol at the intersection and marked the fix for future reference or entered the fix. If he entered the fix, the chart position (and computer latitude and longitude) was updated. The line of bearings were automatically dead reckoned. Set and drift between two visual fixes could also be calculated.

Intended track lines were provided with the digital chart. These lines were part of the chart but could be modified by the operator as required. Based on ship's advance and transfer, present speed and preset rudder angle, the system would calculate the next turn point and display the course and time to that turnpoint, as well as the course of the next leg of the intended track.

Maneuvering Board Solution

In addition to the maneuvering board solution associated with the collision avoidance function, the system also computed course to station. The operator designated a radar target as guide and then typed in own station coordinates. The system calculated and displayed course(s), distance(s), and time(s) to station based on present ship's speed. This information was then automatically updated. Solution(s) based on a trial speed, or on a new course and speed for the guide, was also available as well as one sector of a sector screen.

LOGGING

Data Logger

A thermal printer driven by the AN/UYK-20 computer provided a permanent record of the following parameters: time, ordered course (when in autopilot mode), gyro heading, magnetic heading, fathometer depth, latitutde and longitude, type of fix (e.g., Omega, visual, DR), engine order, ordered rpm, and actual shaft rpm. This information was printed automatically every hour and when any of the following occurred: (a) manual request, (b) course ordered, (c) DR engine ordered, (d) gyro heading or shaft rpm change of a preset amount, and (e) when a new fix was entered.

Voice Recorder

A multi channel continuous running voice recorder was used to log all verbal bridge communications. Two microphones were placed in the pilot house; and the external radio circuits selected at each of the two communication panels were fed directly into the recorder. The tape was automatically time annotated.

Digital Recorder

As part of the computer system, a digital magnetic recorder was provided, which recorded every three seconds, all data provided by the computer to the console displays. This included the collision avoidance and chart data on the main and auxiliary displays as well as the dedicated displays for course, speed, range, bearing and time. The recorder recorded a minimum of four hours on each tape. The tape was replayable on the main console.

MISCELLANEOUS

Alarms

Alarms such as high temperature, steering gear, filament failures, collision avoidance, and autopilot alarms were consolidated into one display located on the overhead fiddleboard. The alarms were divided into two categories: (1) warning and (2) caution. Each category had a separate panel, light color and audible alarm. Alarms were acknowledged by pressing a button on either section of the console. This silenced the audible alarm but the visual indication remained lit until the alarm condition was corrected.

Omega Navigation System

An automatic Omega was provided to replace the manual Omega (SRN-12) normally installed in FF-1052 Class ships. It provided a direct and continuous readout of latitude and longitude along with course and distance to preselected way-points. The latitude and longitude were also fed into the computer for chart positioning logging.

Weapons Advisory Panel

A weapons safety display was located on the left console which showed ships heading, weapon order and weapon train on a circular display. It provided target range and bearing on digital displays and also showed variable depth sonar (VDS) transducer depth, fanfare status and radar lock on/sonar contact status. The only output of the panel was the cease fire alarm.

Overhead Pelorus

A pulldown pelorus was mounted in the overhead above the left console. This device consisted of a sight tube which could be pulled down and moved from side to side to improve visibility. The bearing of the sight tube cross hairs was displayed on a digital display and was selectable either as true or relative bearing.

Navigation Lights

Control for all the navigation lights was provided on the right console. In addition to the individual switches for each of the lights, four special function switches were provided. These switches were: Man Overboard, Breakdown, Flight Operation, and All Running Lights On. When the latter was selected, all existing switch settings were overridden and the proper lights were shown.

High Visibility Displays

Large (1 1/2") light emitting diode displays of gyro course, EM log speed, fathometer depth and time were located on the fiddleboard.

Fog Signal Timer

The standard ship's steam whistle was modified to allow push button operation from the console. As part of the modification an automatic fog signal timer was included which sounded the proper fog signals for both inland or international rules of the road.

Clock

A digital clock provided accurate time to the pilot house and to the computer for logging. The clock had a backup battery supply to maintain accurate time during power failures.

RESULTS AND DISCUSSION

GENERAL

The at-sea feasibility demonstration of the IBS was conducted from January through August 1977 with 1800 hours spent underway during this period. Sixty percent (1000 hours) of the underway time was during independent steaming exercises (ISE); thirty percent (500 hours) during open ocean formation steaming; seven percent (125 hours) during piloting; two percent (34 hours) during underway replenishment; and one percent (14 hours) during anchoring. The data presented were collected during each of the operational categories under routine and casualty modes of operation as well as during readiness conditions I, III, and IV. Special evolutions and conditions such as helicopter operations (HELO OPS), man overboard (MOB), emission control (EMCON), and low visibility (LOW VIS) occurred throughout the test period and were sampled under all readiness conditions.

MANNING

A major goal of the program was to determine if a significant reduction in bridge watchstanding requirements could be achieved while maintaining or improving operational effectiveness of the bridge. Specific manning objectives for Condition III and IV independent and formation steaming are presented in the test plan[3]. Figure 2 presents a comparison of typical FF-1052 bridge manning requirements, project manning goals, and bridge manning levels achieved during the IBS evaluation. Figure 2 shows that actual manning levels achieved with the IBS are lower than typical 1052 Class ship bridge manning requirements for all readiness conditions and operations. As an example, actual bridge manning levels achieved with IBS during Condition III independent and formation steaming met the project goal of six watchstanders. The project goal for Condition III manning was three lookouts and three pilot house watchstanders, while actual manning was two lookouts and four watchstanders. The watchstations manned in the pilot house was the Officer of the Deck (OOD), Junior Officer of the Deck (JOOD), Steering and Propulsion (S&P) Operator, and a Quartermaster of the Watch (QMOW).

Comparisons of manning levels for Underway Replenishment, Piloting, and Anchoring are also presented in Figure 2. Actual IBS watchstations manned during all major ship evolutions and readiness conditions is presented in Figure 3. There were certain situations that required augmenting basic watch manning above that shown. One situation requiring watch augmentation was Fleet exercises when a phone talker was added to the watch to allow the S&P Operator to concentrate on ship control tasks without responsibility for internal communications.

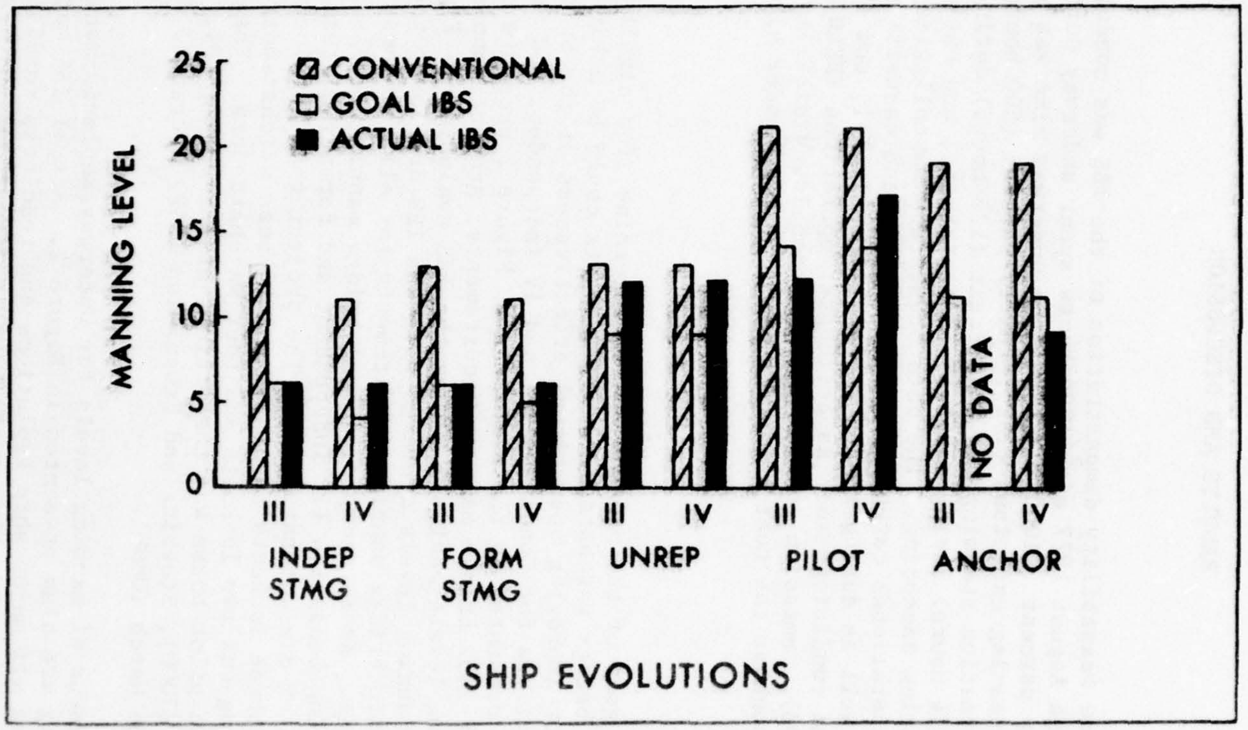

Figure 2 - Bridge Manning Levels

SHIP OPERATION		WATCHSTATION																						
SHIP EVOL.	READ. COND.	OOD	JOOD	S&P OPER	BMOW	QMOW	MSGR	NAVIGATOR	ASST NAV	SAFETY OBS	JL TLKR	JA TLKR	1JV TLKR	1JS TLKR	BR/BR TLKR	BRG RCDR	S&P RCDR	PORT BRG TKR	STBD BRG TKR	FATH OPER	DECK LOG RCDR	FWD LO	AFT LO	TOTAL
IND STMG	I	X	X	X	X	X	X				X	X	X									X	X	11[1]
	III	X	X	X		X																X	X	6[2]
	IV	X	X	X		X																λ	X	6[2]
FORM STMG	I	X	X	X	X	X	X		X		X	X	X									X X	X	13[1]
	III	X	X	X		X																X	X	6[2]
	IV	X	X	X		X																X	X	6[2]
UNREP	IV	X	X	X	X	X				X	X		X		X		X					X	X	12[3]
PILOT	IV	X	X	X	X		X	X	X		X		X	X		X		X	X	X	X	X	X	17

[1] Augmented occasionally by JX Talker and/or Tactical Communicator.
[2] Augmented occasionally by JL Talker.
[3] Augmented occasionally by Messenger or Assistant Navigator.

Figure 3 - IBS Watchstations

EFFECTIVENESS

In addition to demonstrating a significant reduction in bridge watchstander requirements, a goal of the program was to demonstrate that personnel reductions could be achieved while maintaining or improving operational effectiveness of the bridge. The primary means of assessing whether an improvement occurred was through the use of effectiveness ratings. Bridge effectiveness was rated on two five-point scales: (1) a comparative (COMP) scale that compared the effectiveness of IBS with a conventional bridge, and (2) an effectiveness (EFF) scale comparing IBS to each rater's own standard of effectiveness. The COMP scale ranged from 1, "Seriously Degraded", to 5, "Greatly Improved", with 3 representing the same level of effectiveness as a conventional bridge. The EFF scale ranged from 1, "Grossly Ineffective", to 5, "Exceptionally Effective", with 3 representing "Moderately Effective." Raters rated six major bridge functions (i.e., navigation, maneuvering, safety, communications, visual surveillance, and administration) their subfunctions, and overall bridge effectiveness. There were a maximum of 28 items to be rated by each rater (i.e., 6 major functions, 21 subfunctions, and 1 overall rating).

Bridge effectiveness was rated 31 times under a variety of operational conditions. Seventeen of the ratings were by bridge watch officers, twelve by data collection personnel, and two by senior staff officers embarked during an at-sea test period. Since there were only 31 sets of bridge ratings, analysis of ratings by type of ship operation was not possible since it would result in an insufficient sample size for each group of ratings, hence effectiveness ratings for each type of ship operations were pooled for statistical purposes. A check for bias proved negative.

The ratings shown in Table 1 are average values for all raters and ship operations. They are presented for the six major functions of overall bridge effectiveness. The full table of ratings including all subfunctions is presented in Appendix A. Each rating on the COMP scale was compared to the nominal value of 3.00 which would indicate that the IBS was about as effective as a conventional bridge. The obtained ratings on the COMP scale for all major functions shown in Table 1 are all significantly greater than 3.0 except for visual surveillance. This was the only function not affected by IBS equipment or procedural changes. The functional area showing the greatest improvement in effectiveness over a conventional bridge (COMP value of 3.90) is the maneuvering function. This function includes the subfunctions of collision avoidance solutions, maneuvering solutions, and ship control. Appendix A shows COMP scale values of 4.29 and 4.00 for collision avoidance and maneuvering solutions respectively. Both values are significantly greater than 3.00 at the 99% confidence level. While COMP scale values do not indicate the

TABLE 1

BRIDGE EFFECTIVENESS RATINGS

Function	N[a]	SCALES	
		COMP[b]	EFF[c]
Navigation	28	3.68**	3.54**
Maneuvering	30	3.90**	3.63**
Safety	21	3.76**	3.71**
Communications	28	3.50*	3.21 ns
Visual Surveillance	21	3.19 ns	3.29*
Administration	23	3.39*	3.35 ns
Overall	31	3.68**	3.32*

a - Number of ratings.
b - Comparability: IBS vs Conventional
c - Effectiveness: IBS vs raters internal standard.
* - Significant at the 95% confidence level (prob. less than .05).
** - Significant at the 99% confidence level (prob. less than .01).
NS - Non Significant.

absolute magnitude of improvement in effectiveness of IBS over conventional bridges, it does indicate that the automated collision avoidance and maneuvering solution features of the IBS led to a greater relative improvement in effectiveness over any other feature or subfunction of the system.

The ratings on the EFF scale show the same general pattern of results as the COMP scale, however, the values are slightly lower on the EFF scale. All ratings on the EFF scale are significantly greater than 3.00 (moderately effective) except communications and administration. Note however, that these two functions were rated significantly higher on the COMP scale. This is interpreted as indicating that while the IBS was more effective than a conventional bridge in these two functional areas, it was seen as only moderately effective in performing these functions. The generally higher values on the COMP scale over the EFF scale values indicates that while the IBS is seen as being more effective in performing bridge functions than a conventional bridge, it is only slightly more than moderately effective in an absolute sense. Inspection of ratings on the COMP and EFF scales shows that no IBS function or subfunction is rated as less effective than a conventional bridge or less than moderately effective overall.

On the basis of the consistent patterns and levels of ratings on both scales, it was concluded that the IBS improved bridge effectiveness over a conventional bridge in all areas except visual surveillance.

Results of the operator questionnaire summarized in Appendix B shows the same general pattern of improved bridge effectiveness. Question 51 indicates that eighty-three percent (19/23) of the officers and enlisted bridge watchstanders thought the IBS improved bridge effectiveness. Only thirteen percent thought it reduced effectiveness. Question 54 indicates that ninety-one percent (21/23) recommend some form of the IBS for all Navy ships. Acceptance of the IBS was also high. Question 53 shows seventy-eight percent (18/23) satisfied with IBS, while question 52 shows that eighty-two percent preferred standing watch on the IBS as compared with a conventional bridge. Question 50 indicates that seventy-seven percent (17/22) of the watchstanders found their jobs easier with the IBS, and eighty percent (16/20) said standing watch was more interesting with the IBS. Seventy percent (7/10) of the enlisted watchstanders found standing watch more meaningful, while ninety percent (9/10) said that they had more responsibility on watch. Officers found little change in responsibility or meaningfulness in standing watch with the IBS. Increased meaningfulness and responsibility for the enlisted watchstanders is the result of reassignment of bridge watchstanding responsibilities by the IBS.

In addition to supporting the findings of improved effectiveness on the rating scales, the questionnaire results also show that IBS has a high level of acceptability for bridge watchstanders, especially enlisted watchstanders.

SUITABILITY

Because of the relatively small number of system operating hours (2,534) accumulated during the feasibility demonstration and the stage of system development, all suitability data presented in this report are considered preliminary estimates. The intent of collecting and presenting the data is to indicate the feasibility of an integrated bridge system being suitable for Navy use and to identify areas requiring further work. Factors considered under suitability are reliability, maintainability, availability, compatability, and supportability.

Reliability

Mean time between failure (MTBF) is the measure used as the quantitative estimate of system and subsystem reliability. It is computed by the formula:

$$\text{MTBF} = \frac{\text{Total system operating time}}{\text{Number of critical or major failures}}$$

Critical and major failures are those that either prevent the system from providing any assistance in performing bridge functions or from preventing the system from performing in one or more operating modes. Failure of a back-up mode, e.g., nonfollow-up steering, is also considered a major failure. A list of function and equipment losses constituting a major failure appears in the test plan.[3] All other failures are considered minor or non-IBS related. Two exceptions to the original criterion list of equipments for major failure are the digital recorder and the overhead pelorus. The digital recorder had no essential role in performing IBS functions. It was used primarily as a means of recording the main display presentation for possible use as a training aid and for loading program tapes into the IBS computer. This equipment was not used in estimating system reliability.

Initial system design called for the centerline pelorus to be removed from the pilot house and replaced by the overhead pelorus. Major modification of the system late in its fabrication resulted in the centerline pelorus remaining in the pilot house as the main conning station bearing device. This reduced the overhead pelorus to a strictly redundant status as far as system function was concerned. It was left in the system however, to get some diagnostic information on its potential utility as a primary bearing device for ship conning.

Based on a total system operating time of 2,534* hours and 19 critical or major failures, overall system reliability (MTBF) was approximately 133 hours. The AN/UYK-20 accounted for 7 of the 19 major failures, while OMEGA accounted for 3 failures. Major subsystems reliabilities were:

* Total system operating hours exceeded underway time by about 700 hours because the system was used for operator training and system check-out during installation in MCCANDLESS.

- Maneuvering and Navigation; $\text{MTBF} = \frac{2534}{15} = 169$ Hours
- Steering and Propulsion; $\text{MTBF} = \frac{2534}{1} = 2534$ Hours
- Communications; $\text{MTBF} = \frac{2534}{0} =$ Undetermined
- Omega; $\text{MTBF} = \frac{2534}{3} = 845$ Hours

Appendix C is a complete list of all failures.

Maintainability

Three quantitative indices were used to estimate system maintainability. They are: (1) mean time to repair (MTTR), (2) mean time to fault locate (MTFL), and (3) a maintenance support index (MSI).

The MTTR for the system is a function of the active repair time spent on critical or major system failures and the number of failures. Using the same 19 failures as used in computing system reliability, system maintainability was estimated as:

$$\text{MTTR} = \frac{123 \text{ hours}}{19 \text{ failures}} = 6.47 \text{ Hours}$$

Subsystem maintainability estimates are:

- Maneuvering and Navigation; $\text{MTTR} = \frac{91.75}{15} = 6.12$ Hours
- Steering and Propulsion; $\text{MTTR} = \frac{25}{1} = 25$ Hours
- Communications; no major failures
- Omega; $\text{MTTR} = \frac{6.25}{3} = 2.08$ Hours

The seven AN/UYK-20 failures accounted for 56% of the total active maintenance time for the 19 major system failures. The other major contributor to system maintainability came from the data converter unit (DCU). A design modification in the DCU caused an excessive amount of time (25 hours) to be spent on this one failure. Not shown in the above estimates are over 400 hours of nonactive maintenance accumulated by each subsystem due to awaiting spare parts or maintenance assistance from factory representatives.

The second index of maintainability, i.e., MTFL, is not limited to major or critical failures in its computation. This index takes all failures requiring fault location into account along with the total time spent to locate the fault.

$$\text{Total System MTFL} = \frac{134.56 \text{ hours}}{39 \text{ failures}} = 3.45 \text{ Hours}$$

Fifteen of the sixteen failures requiring no fault isolation time were in the "minor" failure category. This indicates that for a large proportion of the minor failures, the cause of the failure was immediately apparent. A comparison of fault location time (134.56 hours) with total active repair time (173.41 hours) shows that three quarters of the total repair time was spent in fault isolation, while only one quarter (45.16 hours) of the time was spent in actual equipment repair.

The third index of maintainability is the maintenance support index. This index, like MTFL, also uses both major and minor failures in its computation. Based on total system operation time and total maintenance manhours,

$$\text{MSI} = \frac{2534 \text{ hours}}{348.72 \text{ MMH}} = 7.27 \text{ or,}$$

one hour of maintenance for every 7.27 hours of operation. Using this value and an estimate of average weekly operating hours, an estimate of the average weekly maintenance workload required to maintain the system was made. It was estimated that slightly over 8 hours of maintenance would be required to maintain the IBS in a typical 60 hour operating week. It is expected that an electronic technician could carry most of this workload with periodic assistance from an interior communications technician and a technician trained in AN/UYK-20 computer maintenance. The average weekly workload of ET's as shown in FF-1052 class ship manning documents ranges between 30 and 40 hours, hence no increase in ship manning requirements should be imposed by an integrated bridge system.

Availability

Operational availability is defined as the degree to which the system was capable of performing its required function. Two measures were used for its computation: (1) operational demand time, and (2) down time. For this analysis, operational demand time is that time from the setting of special sea and anchor detail prior to getting underway to securing of special sea and anchor detail upon returning to port. Down time is that time during which the system was not capable of performing up to minimum specified standards. Minimum standards for performing system functions are presented in detail in the test plan.[3] Total system availability of the IBS during the test period was:

$$A = \frac{\text{operational demand time} - \text{downtime}}{\text{operational demand time}}$$

$$A = \frac{1836 - 473.75}{1836} = .74$$

The majority of downtime was attributable to the Omega System which was responsible for 330.15 hours downtime out of the total system's 473.75 hours downtime. The excessively long Omega downtime was due to a design deficiency in a circuit board which had to be returned to the manufacturer.

Operationa availability computed without the Omega downtime of 330.15 hours included is:

$$A = \frac{1836 - 143.72}{1836}$$

$$A = .92$$

This is reasonably high operational availability.

Compatability

Observations were made during the at-sea tests to serve as a basis for estimating IBS compatability with a navy environment. Components of compatability considered are: platform motion, vibration and shock, temperature, space requirements, air supply, fluctuation and loss of power, and electrical interference.

Platform Motion. During the at-sea tests of IBS several periods of heavy weather were encountered with the ship rolling as much as 25 degrees. No significant problems were encountered in operating the system either in the standing or seated mode. Grab rails provided sufficient hand holds to stand at the console, and the seat design provided adequate restraint for the operators.

Maintenance during heavy ship motion was more difficult. However, captive latches on equipment hatches and roll out drawers provided some safety restraints.

Vibration and Shock. During periods of heavy weather the system encountered relatively high levels of vibrations. Additionally, during gun fire support or ASROC firing, the system was subjected to relatively high shock loads. In no case did these events cause a failure in the equipment.

Temperature. Over the 30 weeks of trials from January to August 1977 a wide range of temperature variations was experienced in the pilot house. It appeared at first that high temperature adversely affected card edge connector contacts in the electronic modular equipments. However, when conditions of high temperature (95 - 100 F) and low humidity were encountered while at Guantanamo Bay, Cuba, no problems were encountered with card seating. This is contrasted with experience while operating in the Bermuda operation area where temperatures of 85 - 95 degrees were encountered with relatively high humidity (80 - 90%). Significant

card seating problems were encountered during this period of high humidity indicating that high humidity along with high temperature was a greater problem than high temperature alone, i.e., reducing equipment temperature by means of air circulation is not as effective in a high humidity environment.

Space Requirements. Most IBS equipment was installed in the pilot house, except for the digital recorder, Omega computer, and voice logger as shown in Figure 1. The width of the pilot house easily accomodated the two main consoles and a 4 foot space for the center-line pelorus. However, the depth of 15 feet in the pilot house was marginal for accommodating the console, chairs, and chart table while still allowing unobstructed movement for the watchstanders. Athwart ships access was adequate.

The placement of the overhead reading lights was acceptable, but an additional red light was added to illuminate the data logger output for night time use.

Air Supply. Air supply in the M&N console was found to be inadequate to remove the warm air inside the consoles. Fans were added to exhaust the air from the M&N and TICC consoles. As a result, the incidence of minor fluctuations in equipment operation was diminished.

Power Fluctuations and Loss of Power. The ability of the IBS system to withstand momentary loss of power and return to normal system operation was tested during engineering casualty control drills. The drill involved loss of power from the main Ship's Service Turbine Generator (SSTG) with emergency power provided by the emergency diesel after a short power outage of approximately 9 seconds. The IBS was subjected to three such 9 second losses of power with no difficulty and complete system operation was restored within a short period.

The only equipment adversely affected by a lowering of voltage was the Auxiliary Display. The picture area was decreased and distorted if the voltage fell below 110V ac.

Supportability

The ship was provided with a complete set of spares for card replacement level maintenance. In general this was adequate to keep the system operational during underway operations. There were however, two instances of extended downtime due to inadequate spare parts support. In one case replacement of a defective spare card for the AN/UYK-20 was expedited by air shipment. In the other case two identical spare cards for the IBS Omega were defective which resulted in the Omega being inoperative until the ship returned to port.

System documentation onboard ship was generally adequate with two exceptions. First, some late design modifications to the system were not included in the onboard documentation. This resulted in a delay in locating a malfunction in the ordered RPM readouts on the S&P console and fiddleboard which was not corrected until the ship returned to port.

Secondly, documentation was inadequate in the built-in fault isolation feature of the M&N console. Specifically, there was inadequate explanation of the fault isolation tests to be performed on the M&N maintenance panel. This resulted in a considerable expenditure of maintenance time and resources to correct one of the failures to the M&N console. It also inflated two of the maintainability indices: MTFL and MSI.

In spite of these problems of inadequate documentation and faulty spares, the system was maintained well by ship's force personnel. An Electronic Technician, an Interior Communications Technician, and an Electronic Warfare Technician with AN/UYK-20 experience performed all organizational and some intermediate level maintenance on the system. A contractor technician was onboard during all but one five-week underway period as a maintenance consultant in the event ship's force maintenance personnel required assistance.

Contractor training on the operation and maintenance of the IBS was deficient in hands-on training time available. Contractor training was conducted during equipment installation and check-out, reducing available time for hands-on training. Only 8 of the 23 watchstanders who received operator training rated it as adequate. Maintenance training was rated by two of the technicians as inadequate for fault detection and location, and parts removal and repair. Only system check-out and parts replacement training were rated as adequate. In general, the technicians felt that they were adequately familiar with maintenance documentation but that documentation and training was inadequate for diagnosis below the block diagram level. Both technicians indicated that conditions for training were disruptive because of the higher priority of system installation and check-out.

IMPACT OF IBS FAILURES/CASUALTIES

The operational impact of major IBS equipment failures is presented in this section. Only failures that resulted in the loss of one or more bridge functions are presented here. By definition, minor failures did not result in the loss of a bridge function because of redundant and back-up modes available.

AN/UYK-20 Digital Computer

There were seven major computer failures during the at-sea test period. These failures resulted in disruption in the maneuvering and navigation functions of the bridge. Automatic solution of collision avoidance and maneuvering problems was lost as well as automated

piloting solutions in conjunction with the digital chart piloting display. Computer failures did not affect the presentation of raw radar on the main display, hence target position data was still available. Additionally, the SPA-25 radar repeater located next to the chart table was available as a back-up for collision avoidance and maneuvering solution inputs to conventional manual maneuvering board solutions. These failures did not necessitate manning augmentation to the bridge watch, but did alter the location of some watchstanders, e.g., the JOOD spent more time at the SPA-25 and chart table and less time at the M&N console.

Loss of the computer also caused data logger failure which required manual recording of information by the QMOW until the computer and data logger were again operational.

Digital Scan Converter

One failure of the digital scan converter occurred early in the test program resulting in the loss of all radar from the IBS main display. This failure caused temporary interference with the maneuvering function. Automatic target tracking of previously acquired targets was not entirely lost. Even though target CPA information was continuously updated and displayed on the auxiliary display, the bridge watch elected to manually plot targets using the SPA-25 repeater rather than depend on IBS target information. Acquisition of new targets with the IBS was still possible by using the guard rings and the hook capability in the manual acquisition mode, but this was not utilized.

Data Converter Unit

There were three failures of the DCU during at-sea tests. Two of the failures caused disruptions in the maneuvering function by inactivating the M&N console pushbuttons and in turn the automated solution capability of the IBS. The radar and target symbology displayed on the main and auxiliary displays became locked or static, hence the SPA-25 repeater was used for radar display information.

The other DCU failure caused a loss of the four-large scale displays of course, depth, speed, and time on the overhead fiddleboard. This resulted in a minor interuption in the maneuvering and navigation functions by requiring watchstanders to obtain this information from backup displays which were less convenient to read.

Automatic Omega

There were two major failures of the automatic Omega equipment which impacted on the bridge's navigation and administrative functions. When the automatic Omega failed, the bridge depended more heavily on the standard ship's Omega, LORAN, radar, and celestial inputs for navigation. Automatic logging of the ship's Omega position was also lost when the IBS Omega was inoperative. This resulted in the need for manual recording of

position by the quartermaster which resulted in a greater expenditure of time by the bridge watch to perform bridge functions.

Another result of the Omega being down was that it could not be used as a position reference by the M&N console when using the digital chart for piloting. Position reference data, i.e., latitude and longitude had to be entered manually on the M&N console keyboard. The total impact of the Omega casualties on bridge performance was an increase in manual operations.

Cue Generator

The cue generator often functioned erratically when exposed to high humidity and temperature causing main display symbology to be distorted. This affected the visual symbology on the maneuvering display but not the actual target tracking or automatic solution capability. Target and solution information continued to be displayed correctly on the auxiliary display.

Auxiliary Display

This unit was commercial grade equipment which exhibited a susceptability to low supply voltage. Low voltage compressed the displayed graphics, sometimes to the extent that part of the display was unreadable. This required an adjustment to the display to make it readable. When this occurred the M&N console was unusable by the bridge watch. The casualty interfered with the maneuvering and navigation functions of the bridge until the proper adjustments were made. During the period of interruption the bridge watch performed the maneuvering and navigation functions manually.

DESIGN CONSIDERATIONS

The results presented below are based on direct observations by project officer personnel and questionnaire results, summarized in Appendix D.

Stand-Up/Sit-Down Ship Control Position

Adjustable chairs were installed at each of the main IBS consoles at about midway in the trials period. S&P operators experienced no difficulty in accessability to controls from a standing position and only one reported difficulty from the seated position. About half of the S&P operators reported difficulty reading displays from their station. This primarily occurred while seated with the sun reflecting off the console panel. All S&P operators indicated the chairs improved bridge effectiveness by reducing fatigue. Officers occasionally used the chair at the M&N console. The S&P operator's chair, when stowed in the full back position interferred somewhat with personnel movement in the pilot house.

EOT/RPM Device. The single lever EOT/RPM device enabled the S&P operator to make rapid and precise changes in engine orders to Main Control. Eighty percent of the watchstanders (20/25) indicated the single lever EOT/RPM device improved bridge effectiveness. One minor problem experienced with the device was lack of one-to-one correspondence between click-stops on the EOT thumbwheel and changes of RPM orders in Main Control, e.g., moving the thumbwheel one stop sometimes resulted in a two RPM change in engine orders in Main Control.

Steering. The steering feature most often used was the autopilot. Ninety two percent (22/24) indicated the autopilot feature improved bridge effectiveness. It also improved bridge efficiency by reducing the workload of the S&P operator allowing him to concentrate on internal communications tasks.

The autopilot was capable of holding the ship on course in various sea states. In sea state (SS) 4 the average deviation from ordered course was 2.65 degrees. The average overshoot following course changes was 2.66 degrees in SS4. In SS3 the autopilot held the ship within a maximum of 1.42 degrees of ordered course. The average overshoot following course changes in SS3 was .76 degrees. In SS1 and SS2 the course-holding performance was even better: average course deviation was .88 degrees, while average overshoot after course changes was .67 degrees.

This data is based on approximately 13 hours of observation under a variety of environmental conditions. Autopilot settings such as "weather adjust", "rudder limit", and "rudder multiplier" varied considerably depending on sea and wind conditions as well as the individual preferences of each conning officer.

Remote control of autopilot from CIC was used extensively during ASW exercises. Seventy-five percent (15/20) of the watchstanders who used it said the remote autopilot improved bridge effectiveness. Twenty-five percent (5/20) said it did not improve it, while the remaining personnel had no opinion sice they had not seen it used this way. Two suggestions made for improvement of the remote feature were the inclusion of a rudder angle input and a method of having the heading order indicator in the pilot house automatically track the input from CIC. This latter improvement would reduce the potential for a heading error in the event steering control were suddenly shifted from CIC to the bridge.

Other features of the steering system, e.g., nonfollow-up rudder control and automatic shifting of steering motors, were not required during the at-sea trials since no steering emergency occurred. When simulated casualty/emergency drills were conducted to test the nonfollow-up control, it was found that constant attention was required by theS&P operator while steering in nonfollow-up, which meant he could not safely perform any other tasks while steering in this mode.

Automated Maneuvering/Collison Avoidance Solutions. Automatic detection and acquisition of surface targets was infrequently used because it was too sensitive to radar clutter and sea return. Seventy seven percent of the officers (10/13) said that automatic acquisition did not improve bridge effectiveness. Automatic tracking of targets was used extensively by the bridge. Automatic computation of target course and speed was generally available in less than one minute from the time a target was acquired and complete CPA information was available in a little over two minutes. Comparison of IBS with CIC tracking capability showed that estimates of target course were within one degree of each other while speed estimates were generally within a knot. These data were collected during a zig-zag tracking exercise with another ship at a range of about 18,000 yards.

During a series of high-speed tracking exercises with a patrol gunboat (PG) the capability of the IBS to automatically track these targets was tested. With the PG travelling in excess of 25 Kts and making hard turns, the IBS frequently dropped track. A modification to the computer software would be required to improve the high-speed automatic target tracking performance of the IBS since this capability was not in the design specifications.

Automatic tracking and continuously updated CPA information in graphic and alphanumeric form were judged by all bridge watch officers as among the most useful capabilities of the IBS. The automatic tracking and display of collision avoidance information also was judged as greatly improving bridge effectiveness. This is reflected in the high ratings of effectiveness for the maneuvering function as shown in Table 1 (the maneuvering function includes collision avoidance, maneuvering solutions and ship control).

With the exception of equipment reliability, the only problem encountered with the automatic tracking feature was an occassional conflict between the short range collision avoidance requirements and the long range surveillance requirement. Close-in targets were difficult to track automatically when the radar was adjusted for long range search. The initial IBS design included a short range radar for providing inputs but this was deleted due to funding constraints.

The automated maneuvering solution capability of the IBS was used extensively by the bridge. According to the watch officers, the most useful feature was the automatic course to station solution. Automated sector screen solutions were also judged to be useful. With the exception of repair and junior officer training periods, the automated maneuvering solution feature of the IBS was the primary method of computing maneuvering solutions. All watch officers indicated that automatic computation of own ship course and speed to station improved performance and efficiency of the maneuvering function.

Automated Piloting. During piloting, the ship used all available position information regardless of its source. While the conventional chart was used for position fixing using visual aids, the digital chart matched to the radar display on the M&N console was used by the OOD and CO for comparative purposes. The digital chart and radar display were matched by automatic radar tracking and DR inputs from the M&N console and adjustments for set and drift in the DR mode was accomplished by slewing the chart to match the radar display. Seven watch officers (64%) said that the digital chart capability improved piloting effectiveness. Four (36%) said it did not. Two did not respond. The major objections raised to automated piloting information was the possibility of inaccurate information at very close range if the radar were adjusted for long range, and the possible clutter of symbols on the display. In general, the usefulness of the automated capabilities of the M&N console are dependent on the condition and adjustment of the ship's search radar. Displayed symbols can be selectively removed from the main display if clutter becomes a problem.

The automated piloting feature dramatically demonstrated its effectiveness in reduced visibility situations. On one occasion the ship piloted into Norfolk harbor in a dense fog using only radar inputs and the digital chart. Other ships in the area delayed entry into the harbor until the fog had cleared enough to use visual bearings for piloting. That flexibility plus the ability to use magnetic compass inputs in the event of a "lost gyro" provided additional back-up capability not presently available on Navy ships.

Automatic Open Sea Navigation. The ship used conventional means to fix its position in the open ocean. The automatic Omega was used for providing waypoints, and for initial positioning of the digital chart. It also provided continuous updated position inputs to the M&N console.

The automatic Omega was seen as improving bridge effectiveness by less than half of the bridge watch. Its most useful feature was reported to be its immediate and continuous digital display of latitude and longitude. The bridge watch was about split on its preference for the automatic Omega and the ship's Omega. The average fix disparity between the two devices was about two-and-a-half nautical miles, while the disparity between the IBS Omega and radar fixes was about one-and-a-half miles.

Integrated Communications. The availability of all internal communications circuits to the S&P operator made it possible for him to perform routine communications along with his other tasks, thus eliminating the need for a JL phone talker during most routine ship operations. This required that the OOD and JOOD assume some of the internal communications workload when the S&P operator was busy on another circuit or performing ship control tasks. Based on over 70 hours of observation under all operating conditions it was found that the S&P operator performed about half (52.5%) of the communications tasks on the bridge. The OOD performed almost 30% while

the JOOD performed just over 15%. The QMOW, JL talker, messenger and other watchstanders performed the remaining communication tasks during conditions of increased tempo of operations, such as Fleet exercises, underway replenishment, special sea detail, etc.

Integration of internal communications was viewed by all enlisted watchstanders as improving bridge effectiveness. Only seven of thirteen (54%) officers said it improved effectiveness. Two objections the officers had with integrated communications were equipment unreliability and the increased potential for task overload or interference on the part of the S&P operator. The enlisted watchstanders also cited equipment problems as affecting their communication performance. Faulty microphones on the headsets, malfunctioning pushbuttons on the administrative circuit panel, and poor readability of the circuit buttons were cited as specific problems with the integrated communications system.

The integrated communication equipment was judged by 77% of the watch officers to be located correctly for effective operation. Volume controls on the radio handset panel and on the overhead speakers was redundant. This redundancy actually degraded effectiveness by making adjustment of speaker volume unnecessarily complicated and confusing.

Manned and Ready System (M&R). The manned and ready (M&R) system was used throughout the trial period when setting special evolutions and increased conditions of readiness. By using this nonverbal means of determining ready status of remote stations the noise level on the bridge was substantially reduced. Occasional verbal promptings over the SP phones were required when a station was slow in reporting. Sixty two percent of the watch officers (8/13) said that the IBS M&R system was more effective than the SP phone method in determining the readiness status of remote stations.

A minor limitation of the M&R system was that each evolution listed on the fiddleboard had a fixed set of stations associated with it which did not allow for variations in the number or location of remote stations associated with all variations of evolutions. This lack of flexibility sometimes resulted in the bridge not being sure if all stations required for a particular evolution were actually manned and ready. This situation would not arise once all stations were known and labeled on the fiddleboard.

Automated Logging. The data logger and voice recorder made it possible to cease keeping a written deck log during the at-sea trials period. A waiver was granted from CNO for the duration of the testing. The automatic logger and voice recorder continuously recorded all information legally required of the deck log. Ninety percent (10/11) of those responding to this item said that these devices improved bridge efficiency. Some problems encountered with these devices include difficulty in retrieving recorded voice information, no warning signal when data logger

ceased to record, and the location of overhead microphones were not adequate to pick up all verbal communications in the pilot house. Also, the automated devices did not record gyro error or weather observations. The magnetic compass log and weather log continued to be maintained manually by the QM's.

Navigation Lights Panel. The concept of controlling navigation lights from the S&P operator's position was not adequately evaluated because of compatibility problems with the existing lighting control panels which were left in place and were fully operational during the evaluation. However, the special evolution light switches were used and judged to improve bridge effectiveness.

Overhead Pelorus. The pull-down overhead pelorus was originally designed to replace the centerline pelorus. Modification to system design prior to installation resulted in keeping the centerline pelorus. Less than half (6/13) of the officers felt that the overhead pelorus was a useful device as incorporated. Night lighting and magnification were suggestions made to increase its usefulness.

Weapons Advisory Panel. The weapons advisory panel did not operate properly during the evaluation period, therefore it was not used and a meaningful evaluation was not possible.

CONCLUSIONS

The feasibility of reducing bridge watch manning while maintaining or improving operational effectiveness with the IBS was conclusively demonstrated during the test and evaluation period onboard MCCANDLESS. Based on effectiveness ratings and questionnaire responses, operational effectiveness of the IBS in performing bridge functions was significantly improved over conventional bridges. While some specific equipments were judged ineffective, they did not degrade the performance of the bridge as a whole or any of the major bridge functions. It is therefore concluded that the primary goal of the project to demonstrate a reduction in bridge watchstanding while maintaining or improving effectiveness with the IBS was achieved. The secondary objectives of the project were also achieved with minor exceptions.

The functional areas showing the greatest improvement in bridge effectiveness are navigation and maneuvering. The specific features responsible for this increase are the autopilot, single lever EOT/RPM device, automatic tracking of targets, automated collision avoidance and maneuvering solutions, and automatically and continuously updated piloting information graphically displayed in real time for referral by the bridge. These features, along with integrated communications and automated logging made it possible to significantly reduce bridge manning by redistributing the workload of the watchstanders. It is possible that further automation of logging (e.g., weather reports), improved equipment reliability, and improved training for new watchstanders could lead to further reductions in Condition III and IV manning requirements, and to even greater improvements in effectiveness. Continued system development and full operation evaluation are needed to demonstrate these improvements.

While some difficulties were encountered in meeting some of the suitability goals, full system suitability is feasible with the implementation of design changes identified during this feasibility demonstration.

Relocation of equipment such as the scan converter, AN/UYK-20, and video processor, to an environmentally controlled space such as CIC equipment room should improve the reliability and maintainability of the system. Access to the system for maintenance without interfering with bridge operations would also be improved by relocating the equipment.

Although maintenance training and documentation were inadequate, onboard technicians, with some assistance from contractor representatives, were able to maintain the system without exceeding their normal average weekly workload. With improved system design, complete documentation, and maintenance training, an integrated bridge system would not impose a significant increased workload on ship technicians.

Overall and specific design features of the IBS led to improved bridge efficiency and effectiveness. Design improvements are needed in the areas of internal communication panels, LED displays on the fiddleboard, overhead pelorus, collision avoidance alarms, single RPM change orders to main control, voice recording of bridge activities, operator's chairs, navigation lights panel, digital recording of M&N functioning, automatic tracking of high-speed targets, power supply isolation, and general arrangement of integrated bridge equipment to allow unobstructed movement of pilot house personnel.

RECOMMENDATIONS

It is recommended that further integrated bridge development continue and that the following changes be incorporated into future bridge system designs:

Design all equipment critical to ship safety to meet current military standards and specification.

Relocate all card-holding electronic equipments such as the cue generator, scan converter, and AN/UYK-20 computer to a temperature and humidity controlled environment.

Modify the computer software to improve automatic detection and tracking of high-speed targets.

Eliminate the present digital recorder and provide an alternative means of loading the computer program tapes.

Provide better isolation between IBS power supplies and non-IBS related bridge equipment power requirements.

Suppress the collision avoidance alarms such that the audio portion does not reactivate on the same target following momentary deactivation of the alarm by the appropriate console alarm acknowledge button.

Remove the weapons advisory panel from the system.

Remove the volume control from the overhead external communications circuit speakers and keep the volume controls on the IBS communication console panels.

Improve the reliability of the administrative circuit panel buttons and provide a more positive means of detecting the circuit receiving an incoming call.

Improve the reliability of the sound-powered phone headset microphone.

Provide the capability to place any combination of sound-powered phone circuits on the communications panel speakers.

Remove the navigation lights control panel from the console with the exception of the special function lights.

Make high visibility displays (COURSE, SPEED, DEPTH, and TIME) on the fiddleboard readable from the port and starboard pilot house hatchways.

Increase the number of voice recorder microphones in the pilot house with separate recording channels for each microphone, and provide the capability to select or mix any combination of channels on playback.

Remove the overhead pelorus sighting tube.

Provide a light on the data logger for reading entries at night.

Provide a warning light and/or alarm to indicate that the data logger has stopped recording.

Provide a means of making single, discrete RPM propeller order changes from the S&P console to main control.

Recess the operator chair rails and improve chair design.

Reduce or eliminate the problem of glare off the front panels of the main consoles.

Improve the visibility over the top of the main consoles by relocating or lowering the consoles.

Reconfigure the integrated bridge system and other bridge equipment to provide freer unobstructed personnel movement in the pilot house.

Provide detailed system documentation to reduce fault isolation time.

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APPENDIX A

BRIDGE EFFECTIVENESS RATINGS

BRIDGE EFFECTIVENESS RATINGS

BRIDGE FUNCTION	Item No.	SCALE: COMP (N)	COMP Avg. Rating	EFF (N)	EFF Avg. Rating
NAVIGATION	31	(28)	3.68	(28)	3.54
POSITION FIXING	32	(27)	3.63	(27)	3.48
NAVIGATION SOLUTIONS	33	(24)	3.71	(24)	3.37
MANEUVERING	34	(30)	3.90	(30)	3.63
COLLISION AVOIDANCE SOLUTIONS	35	(27)	4.29	(27)	4.00
MANEUVERING SOLUTIONS	36	(28)	4.00	(28)	3.64
STEERING & PROPULSION	37	(31)	3.29	(31)	3.42
SAFETY	38	(21)	3.76	(21)	3.71
WEAPONS	39	(6)	3.38	(6)	3.38
NAVIGATION LIGHTS	40	(17)	2.82	(17)	2.94
ALARMS	41	(15)	3.67	(15)	3.67
PERSONNEL	42	(20)	3.20	(20)	3.55
COMMUNICATIONS	43	(28)	3.50	(28)	3.21
EXTERNAL-ELECTRONIC	44	(26)	3.73	(26)	3.26
EXTERNAL-VISUAL	45	(13)	2.92	(13)	3.23
INTERNAL-VOICE	46	(29)	3.00	(29)	2.82
INTERNAL-NONVOICE	47	(20)	3.85	(20)	3.25
VISUAL SURVEILLANCE	48	(21)	3.19	(21)	3.29
BRIDGE	49	(23)	3.26	(23)	3.34
LOOKOUTS	50	(22)	3.00	(22)	2.91
ADMINISTRATIVE	51	(23)	3.39	(23)	3.34
PASS THE WORD	52	(28)	3.25	(28)	3.25
LOGGING/RECORDKEEPING	53	(29)	3.93	(29)	3.52
TESTS/DRILLS	54	(11)	3.36	(11)	3.27
ROUTINE TASKS/CLEANUP	55	(19)	2.94	(19)	3.05
UNSCHEDULED TASKS	56	(23)	3.0	(23)	2.65
TRAINING	57	(17)	2.82	(17)	2.70
OVERALL EFFECTIVENESS	58	(31)	3.68	(31)	3.32

APPENDIX B

OPERATOR QUESTIONNAIRE RESPONSES

OPERATOR QUESTIONNAIRE RESPONSES

Quest. No.	Question Content	Responses			
1.	Frequency of Equipment Use	Never	Sometimes	Often	
a.	Tactical Information & Comm Console	0	3	10	
b.	M&N Console	1	0	12	
c.	S&P Console	1	9	13	
d.	Navigation Lights Console	2	16	4	
e.	Auxiliary Comms Console	2	6	14	
f.	Fiddleboard	0	7	8	
g.	Overhead Pelorus	4	8	1	
h.	Cardinal Omega System	3	6	2	
i.	Data Logger	4	3	5	
j.	Digital Video Recorder	5	2	3	
k.	Voice Recorder	3	7	3	
l.	Bridge Wing Comms	1	18	2	
m.	Bridge Wing Pelorus	4	4	3	
2.	Number of Watchstanders Judging Themselves Qualified to Operated Each Equipment	No.			
a.	Tactical Information & Comm Console	11			
b.	M&N Console	11			
c.	S&P Console	23			
d.	Navigation Lights Console	23			
e.	Auxiliary Comms Console	23			
f.	Fiddleboard	16			
g.	Overhead Pelorus	12			
h.	Cardinal Omega System	7			
i.	Data Logger	5			
j.	Digital Video Recorder	4			
k.	Voice Recorder	4			
l.	Bridge Wing Comms	23			
m.	Bridge Wing Pelorus	12			
3.	Minimum Skill Level Required to Operate Each Equipment	Number of Responses/Level			
		Nonrated	PO	CPO	OFF
a.	Tactical Information & Comm Console	2	4	0	5
b.	M&N Console	0	5	1	5
c.	S&P Console	21	0	0	0
d.	Navigation Lights Console	20	0	0	0
e.	Auxiliary Comms Console	20	0	0	1
f.	Fiddleboard	8	1	0	2
g.	Overhead Pelorus	6	1	0	1
h.	Cardinal Omega System	0	7	0	3
i.	Data Logger	5	4	0	0
j.	Digital Video Recorder	2	6	0	0
k.	Voice Recorder	2	7	0	1
l.	Bridge Wing Comms	18	0	0	1
m.	Bridge Wing Pelorus	12	0	0	0

Quest.No.	Question Content	Contractor	Ship Staff	OJT
4.	Type/Source of Operator Training			
a.	Tactical Information & Comm Console	9	1	2
b.	M&N Console	8	1	3
c.	S&P Console	14	2	6
d.	Navigation Lights Console	13	2	7
e.	Auxiliary Comms Console	14	2	6
f.	Fiddleboard	8	0	4
g.	Overhead Pelorus	8	0	4
h.	Cardinal Omega System	8	1	3
i.	Data Logger	8	1	2
j.	Digital Video Recorder	6	1	2
k.	Voice Recorder	8	1	2
l.	Bridge Wing Comms	12	2	8
m.	Bridge Wing Pelorus	7	1	4

5.a. Amount of contractor training received (Insufficient response.)

Quest.No.	Question Content	Yes	No	Don't Know
5.b.	Contractor training adequate	8	9	6
6.	Contractor training necessary	14	6	3
7.	Situations interfere with duties	18	6	1
	Equip malf.	4		
	Fleet ops	6		
	Too many tasks	8		
8.	Task overload at watchstation	2	9	0
9.	Ways to reduce task overload			
	Add SP phone talker	7		4
10.	Bridge requires occasional manning augmentation	6	6	1
11.	Bridge occasionally overmanned	12	0	1
12.	Training adequate for information processing	9	1	1
13.	Training adequate for decision making	5	3	3
14.	Training adequate for equipment operation	7	4	0
15.	Special skills needed for processing info	6	7	0
16.	Special skills needed for operating equip	4	8	1

Quest.No.	Question Content	Yes	No	Don't Know
17.	IBS output difficult to interpret	1	11	1
18.	Decision making difficult with IBS outputs	12	0	1
19.	Difficulty in manipulating equipment	13	9	1
20.	Training adequate for interpreting info	9	2	2
21.	Training adequate for taking actions	10	0	3
22.	Training adequate for manipulating equip	7	3	3
23.	Recommend additions to contractor training	8	1	3
24.	Recommend additions to OJT	8	8	7
25.	Actual information processing methods different than in contractor training	2	8	3
26.	Actual information processing methods different than in technical manual	4	6	3
27.	Actual decision making methods different than in contractor training	3	9	1
28.	Actual operating techniques different than in contractor training	2	11	0
29.	Actual operating techniques different than in technical manual	1	10	2
30.	Received contractor assistance in interpreting IBS output	10	3	0
31.	Received contractor assistance in taking actions based on IBS output	3	10	0
32.	Received contractor assistance in equipment operation	12	1	0
33.	Continuous equipment monitoring required	16	7	0
34.	Decision making difficult with IBS	2	10	1
35.	Continuous equipment manipulation required	11	12	0
36.	Task interference from interacting with other watchstanders	5	8	0
37.	Task interference from other sources	7	5	1

Quest. No.	Question Content	Yes	No	Don't Know
38.	Technical manual adequate for describing watchstation interactions	6	6	1
39.	Technical manual adequate for performing watchstation duties	9	0	4
40.	Technical manual adequate for interpreting information	9	1	3
41.	Technical manual easy to understand	17	2	4
42.	Technical manual/OJT conflict	4	6	3
43.	Recommend changes to technical manual	1	6	6
44.	Bridge undermanned	16	7	0
45.	Bridge overmanned	18	5	0
46.	Maintenance technicians and skill level sufficient	0	13	0
47.	Equipment tiring to operate	3	20	0

48. First impression of IBS — Favorable 20 Unfavorable 1 Neutral 1

49. Changes in first impression — Yes 9 No 13
Amount of Change — A little 2 Some 5 A lot 2
Direction of Change — Pos 3 Neg 7

50. Effect of IBS on watch work

Easier	17	Harder	2	No Change	4
More interesting	16	Boring	1	No Change	6
More skills needed	11	Fewer skills needed	8	No Change	4
More meaningful	10	Less meaningful	2	No Change	11
More responsibility	10	Less responsibility	2	No Change	11
Know more about performance	10	Know less about perf.	2	No Change	11

51. Effect of IBS on bridge effectiveness — Improved 19 Reduced 3 NC 1

52. Type bridge watch preferred — IBS 18 Conventional 2 Not Sure 3

53. Satisfaction with IBS watchstanding
Very Satisfied 13 Mildly Satisfied 5 Neutral 3 Mildly Disat 2
Very Disat 0

Quest.No.		Yes	No	Don't Know
54.	Recommend IBS for all ships	21	1	1
55.	Watchstanding more professional with IBS	7	11	5
56.	Effect of own performance on job attitudes	A lot 9	Some 2	None 0
57.	Increased desire to perform well on IBS	10	11	2
58.	Perform better watch on IBS	11	10	2

APPENDIX C

IBS CORRECTIVE MAINTENANCE ACTIONS

IBS CORRECTIVE MAINTENANCE ACTIONS

MINOR FAILURES

EQUIP NAME	TIME TO FAULT ISOLATE	TIME TO REPAIR	TOTAL ACTIVE MAINT TIME	MAINT MANHOURS
CUE GEN	0.03	0.03	0.06	0.06
CUE GEN	0.25	0.25	0.50	1.00
CUE GEN	0.03	0.05	0.08	0.08
DCU	0.35	0.80	1.15	1.15
DCU	0.50	0.67	1.17	2.34
DCU	10.00	0.00	10.00	10.00
SCAN CONV	0.00	0.17	0.17	0.17
SCAN CONV	0.00	0.13	0.13	0.13
VIDEO PROC	2.00	0.00	2.00	6.00
MAIN DISPL	0.08	0.28	0.36	0.36
AUX DISPL	0.00	0.17	0.17	0.34
AUX DISPL	0.17	0.50	0.67	0.67
AUX DISPL	0.00	0.17	0.17	0.17
M&N MISC	0.33	0.25	0.58	1.16
RPM IND	0.02	0.08	0.10	0.10
RPM IND	0.17	0.03	0.20	0.20
MAG TAPE	1.00	0.00	1.00	1.00
MAG TAPE	0.00	0.12	0.12	0.12
MAG TAPE	0.00	0.07	0.07	0.07
MAG TAPE	0.00	0.05	0.05	0.05
MAG TAPE	0.00	0.13	0.13	0.13
MAG TAPE	0.02	0.08	0.10	0.10
VOICE LOG	13.00	11.00	24.00	48.00
DATA LOG	1.00	1.00	2.00	4.00
M&R DISPL	0.02	0.08	0.10	0.10
R M&R BOX	0.00	0.25	0.25	0.25
21MC	0.50	0.25	0.75	0.75
1MC	0.03	0.83	0.83	1.66
1MC	0.25	0.75	1.00	1.00
SP PHONE	1.00	0.50	1.50	4.50
HEADSET	0.00	0.17	0.17	0.17
SHIP ALARM	0.00	0.08	0.08	0.08
PELORUS	0.25	0.25	0.50	0.50
SUBTOTAL	31.00	19.19	50.16	86.41
AVG	0.97	0.60	1.57	2.70
N=32				

ALL FAILURES

TOTAL	131.03	43.27	173.88	345.85
AVG	2.57	0.85	3.41	6.78
N=51				

IBS CORRECTIVE MAINTENANCE ACTIONS

MAJOR FAILURES

EQUIP NAME	TIME TO FAULT ISOLATE	TIME TO REPAIR	TOTAL ACTIVE MAINT TIME	MAINT MANHOURS
AN/UYK-20	0.83	0.87	1.70	3.40
AN/UYK-20	0.08	5.12	5.20	15.60
AN/UYK-20	0.00	0.17	0.17	0.50
AN/UYK-20	0.13	0.27	0.40	0.40
AN/UYK-20	0.02	0.03	0.05	0.05
AN/UYK-20	16.00	0.17	16.17	16.17
AN/UYK-20	28.00	0.50	28.50	57.00
DCU	2.58	0.20	2.78	5.57
DCU	1.42	0.08	1.50	1.50
DCU	23.00	2.00	25.00	50.00
VIDEO PROC	0.08	0.17	0.25	0.25
VIDEO PROC	6.00	3.00	9.00	18.00
VIDEO PROC	1.00	1.00	2.00	4.00
AUX DISPL	1.50	0.50	2.00	4.00
AUX DISPL	3.00	3.00	6.00	6.00
SCAN CONV	12.00	6.00	18.00	72.00
OMEGA	4.00	1.00	5.00	5.00
OMEGA	0.08	0.50	0.58	0.58
OMEGA	0.33	0.33	0.67	0.67
SUBTOTAL	100.05	24.91	124.97	260.69
AVG	5.27	1.31	6.58	13.72

APPENDIX D

DESIGN CONSIDERATIONS

QUESTIONNAIRE RESPONSES

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DESIGN CONSIDERATIONS QUESTIONNAIRE RESPONSES

Quest. No.	Question Content	Question Responses[1]		
PART I		Yes	No	Don't Know
1.	Autopilot improves efficiency	12	0	0
	Autopilot improves effectiveness	22	2	1
2.	Remote autopilot improves efficiency	8	3	1
	Remote autopilot improves effectiveness	15	5	5
3.	Problems encountered with autopilot:	6	19	0
	setting controls	3		
	standardizing procedures	3		
4.	Single-lever EOT/RPM device improves efficiency	10	3	2
	Single-lever EOT/RPM device improves effectiveness	19	4	2
5.	Problems encountered with EOT/RPM device:	4	20	1
	bridge-main control RPM compatability	4		
6.	Automatic steering motor shift improves efficiency	8	2	5
	Automatic steering motor shift improves effectiveness	8	2	5
7.	Auto start back-up motor improve efficiency	7	2	6
	Auto start back-up motor improve effectiveness	7	2	6
8.	Problems encountered with auto steering (inadequate responses)			
9.	S&P controls easy to operate	24	1	0
10.	S&P controls located for effective use	23	2	0
11.	S&P displays easily readable	13	12	0
12.	Console chairs improve effectiveness	10	0	0
13.	Console fold-out writing tables useful	7	18	0
14.	Visibility good while standing at console	10	0	0
	Visibility good while seated at console	4	6	0
15.	Bridge layout improves bridge efficiency	12	1	2
	Bridge layout improves bridge effectiveness	21	4	0

[1] The number of responses varied for each question.

Quest.No.	Question Content	Yes	No	Don't Know
PART II				
16.	Automatic acquisition and tracking improves Collision avoidance effectiveness	10	3	0
17.	Automatic acquisition necessary	3	10	0
18.	CPA graphics on main display presents CA information effectively	13	0	0
19.	Auxiliary display CPA information displayed for effective collision avoidance decisions	13	0	0
20.	Guard rings effective approach to target detection	5	8	13
21.	Guard ring number and range adequate	6	7	0
22.	Most effective combination of target acquisition and tracking:			
	manual acq/auto trk	8		
23.	Guard rings and alarms improve effectiveness	6	7	0
24.	Most effective automatic CA capability:	auto trk/guard ring/graphics		
	Least effective automatic CA capability:	auto acq		
25.	Additional CA capabilities required	0	6	7
26.	CA capabilities not necessary (auto acq)	6		7
27.	Target course and speed information useful for CA decisions	13	0	0
28.	Trial speed useful for computing CA solutions	11	0	2
	Trial speed useful for computing maneuvering solutions	13	0	0
29.	Best automated maneuvering solutions			
	course to station	7		6
30.	Automatic sector screen improves effectiveness	12	0	1
31.	Automatic computation of own ship course and speed improves maneuvering	12	0	1
32.	Automated computation feature contributing most to maneuvering effectiveness			
	course to station	7		6

Quest.No.	Question Content	Yes	No	Don't Know
PART III				
33.	Automatic open-sea navigation improves efficiency	7	3	3
	Automatic open-sea navigation improves effectiveness	7	3	3
34.	Automatic open-sea navigation capability contributing most to bridge efficiency			
	Automatic open-sea navigation capability contributing most to bridge effectiveness			
	Immediate digital posit.		7	6
	Immediate digital posit.		7	6
35.	Recommend changes to automatic open-sea navigation:			
	Improve Reliability	6		
36.	Problems encountered with automatic open-sea navigation:			
	Unreliable	6		
37.	Preferred approach to open-sea navigation:			
	IBS 4 Conventional 6			3
PART IV				
38.	Digital navigation char easy to use	12	0	1
39.	Digital navigation chart improve piloting effectiveness	7	4	2
40.	Digital chart - radar match-up difficult	2	9	2
41.	Problems encountered in radar-chart match-up:			
	sea return in short range	4		
42.	Digital chart symbology easy to use	10	2	1
43.	Main display information useful in piloting	10	2	1
44.	Digital chart piloting may degrade effectiveness	7	4	2
45.	Visual fix input to IBS position fixing improves effectiveness	9	2	2

Quest.No.	Question Content	Question Responses		
		Yes	No	Don't Know
46.	Method of marking "Notice to Mariners" changes are effective	0	5	8
PART V				
47.	Integrated external voice communications improves effectiveness	10	3	0
48.	External communications control panels located for effective use	10	1	2
49.	Integrated internal voice communications improves effectiveness	18	5	2
50.	Internal communications control panel located for effective use	21	2	2
51.	Most effective internal communications feature:			
	consolidation/centralization	12		
52.	Manned and ready system more efficient for determining station readiness	8	5	0
53.	Manned and ready system more effective for determining station readiness	8	5	0
54.	Problems with manned and ready system:			
	forget to use it	4		
	verbal prompting	3		
PART VI				
55.	Recording devices meet legal and administrative requirements	4	3	6
56.	Recorded information accessable for review	3	3	7
57.	Problems retrieving recorded information	(insufficient responses)		
58.	Difficulties encountered operating recorders	(insufficient responses)		
59.	Information lost because of recorders	4	2	7
60.	Recorders improve bridge efficiency	10	2	3

Quest. No.	Question Content	Question Responses		
		Yes	No	Don't Know
61.	Recorders used for other purposes	0	7	6
62.	Recommend improvements in recording devices:			
	more convenient playback/review	6		
63.	Tactical publications location and storage adequate	3	11	1
PART VII				
64.	Overhead pelorus useful	6	6	1
65.	Overhead pelorus effectively located	5	6	2
66.	Recommend changes to overhead pelorus:			
	night illumination	6		
67.	Primary use of overhead pelorus:			
	bearing drift on tgts	4		
68.	Ways to improve visibility from pilot house:			
	move console back from window	4		
69.	Full 360° visibility from pilot house necessary	8	4	3
PART VIII				
70.	Weapons safety display needed on bridge	5	5	3
71.	Weapons safety display used to monitor weapons safety	2	7	4
72.	Weapons safety display provides all necessary information	3	3	7
73.	Weapons safety display provides all information necessary to take preventive action	3	3	7
74.	Cease fire alarm effective in preventing accidents	2	2	9

Quest.No.	Question Content	Question Responses		
PART IX		Yes	No	Don't Know
75.	Ship's alarms located for effective action	11	2	0
76.	Ship's alarms designed to prevent inadvertent operation	3	7	3
77.	Warning and caution digital readouts visible from all bridge locations	5	7	1
78.	Large scale digital displays useful	10	2	1
79.	Recommend changes in fiddleboard:			
	improve digital display visibility	4		
	RPM-astern indicator	2		
80.	Warning and caution alarm information sufficient	9	2	3
81.	Type of hazard identifiable from audio alarms	10	1	2
82.	Alarm acknowledge procedure appropriate	8	2	3
PART X				
83.	Specially programmed lights improve effectiveness	6	6	3
84.	Add/remove lights from navigation lights panel:			
	remove panel from console	6		
85.	Adequate location and labelling of lighting controls	9	2	4
86.	Filament test feature located for effective use	5	3	7
87.	Recommend changes to specially programmed lights	(insufficient response)		

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